Modeling 3D Spatially Distributed Water Fluxes in an Andisol under Banana Plants

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Introduction

Humid tropical climate : 2.5 à 4.5 m water.year^{-1}
with intensities > 70 mm.h^{-1}
Main stemflow around the pseudo-stem

Stemflow x 10 to 35 the incident rainfall + throughfall

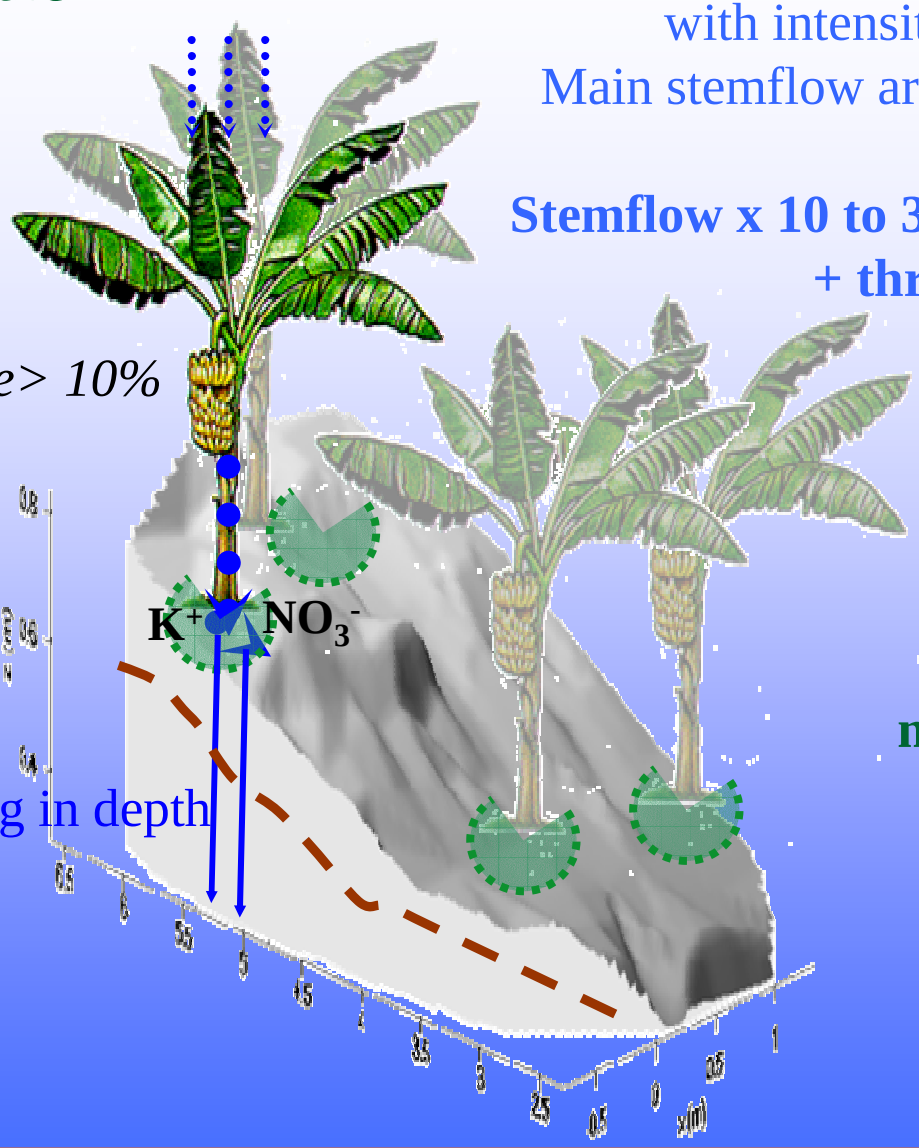
Bassette and Bussière, 2004

Atmosphere

Interface

slope> 10%

Plant



Interface

Leaching in depth

Soil

KNO_3 supply:
massive and localized around the stem
(400 kg N/ha/y
800 kg K/ha/y)

Godefroy and Dormoy., 1988

Objectives

- **Evaluate distributed subsurface water fluxes under banana plants** and to use the collected data to evaluate and **numerically simulate these distributed water fluxes** using the HYDRUS software package.

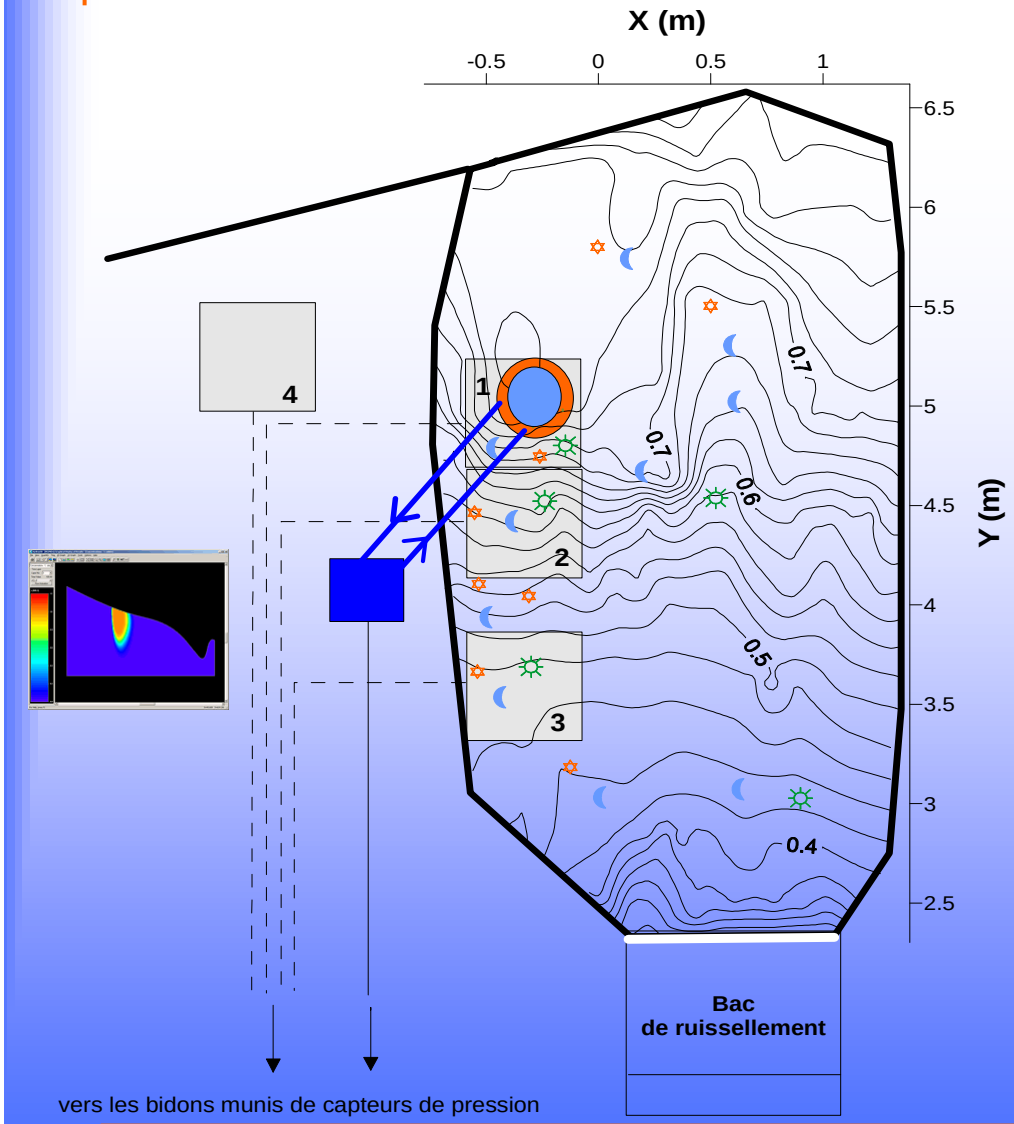
- Hence, the study had several phases:

  - (i) **laboratory experiments** to obtain soil hydraulic parameters characterizing the unsaturated hydraulic conductivity function, *K(h),* and the soil water retention curve, *θ(h);*

  - (ii) **field experiments** to measure surface water fluxes (stemflow and throughfall) and subsurface pressure heads and drainage fluxes;

  - (iii) **numerical modeling** using the HYDRUS model to predict distributed water fluxes and compare them to the *in situ* drainage measurements.

Schematic representation of the flow domain



Faux-tronc du bananier

Tensiomètres de surface

Tensiomètres à 25 cm de profondeur

Tensiomètres à 55 cm de profondeur

Collerette

Tuyaux

Tôles

Lysimètres

Partiteur de stemflow

Schematic representation of the flow domain

HYDRUS 3D model simulate Darcian water flow in a three-dimensional flow domain in the unsatured-saturated flow system

Richards Equation of water transfer

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K\left(\frac{\partial h}{\partial x}\right)\right] + \frac{\partial}{\partial y}\left[K\left(\frac{\partial h}{\partial y}\right)\right]\frac{\partial}{\partial z} + \left[K\left(\frac{\partial h}{\partial z} - 1\right)\right] - S$$

Run-off, soil evaporation, plant nutrition

Mualem -Van Genuchten (1980)

Water retention curve (Wind measurements)

$$\theta(h) = \frac{\theta_s - \theta_r}{(1 + |\alpha h|^n)^m}$$

Hydraulic conductivity curve (Double ring Infiltrometers)

$$K(h) = K_s S_e^{\,l}\left[1 - (1 - S_e^{\frac{1}{m}})^m\right]^2$$

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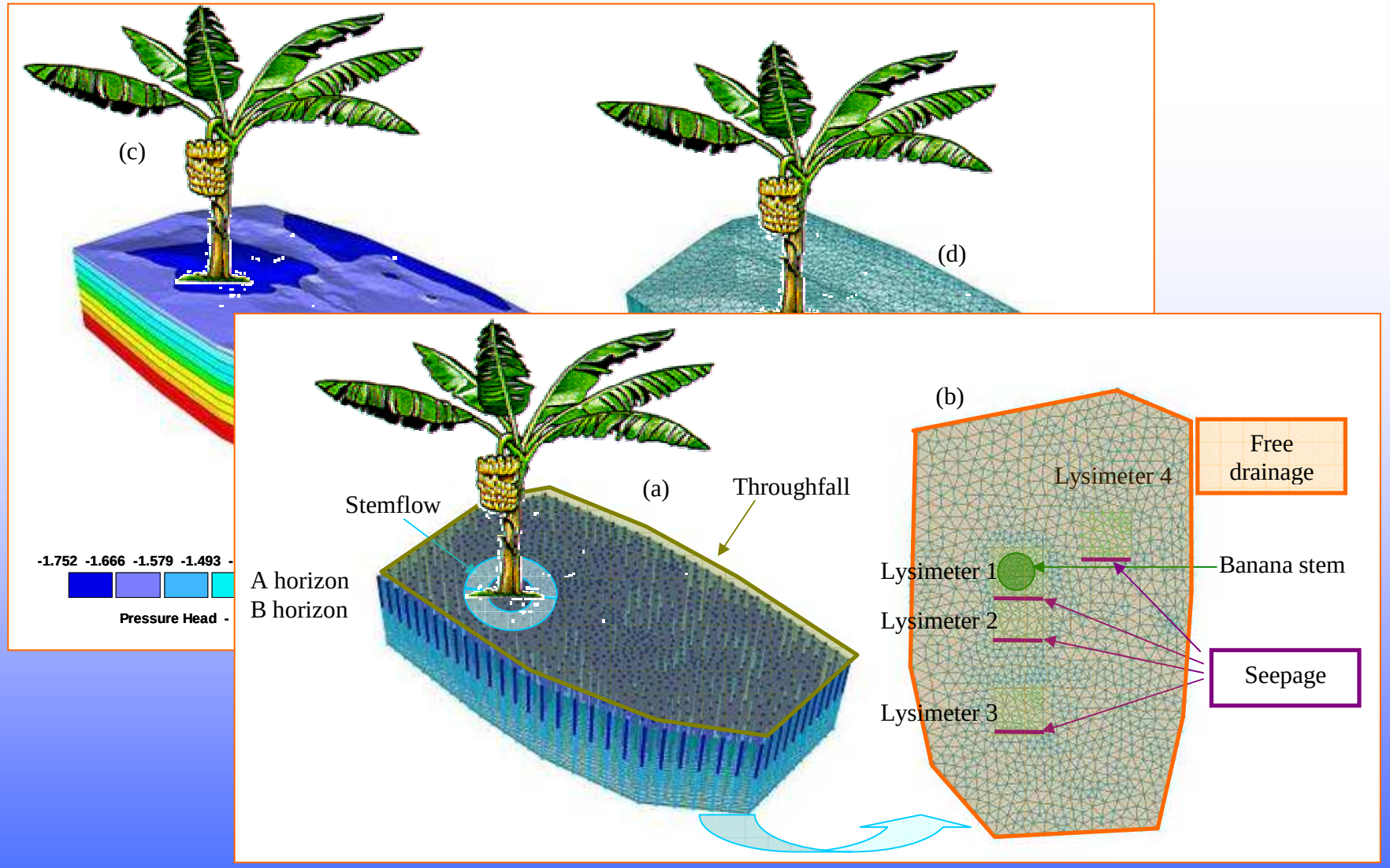


Results : Soil properties

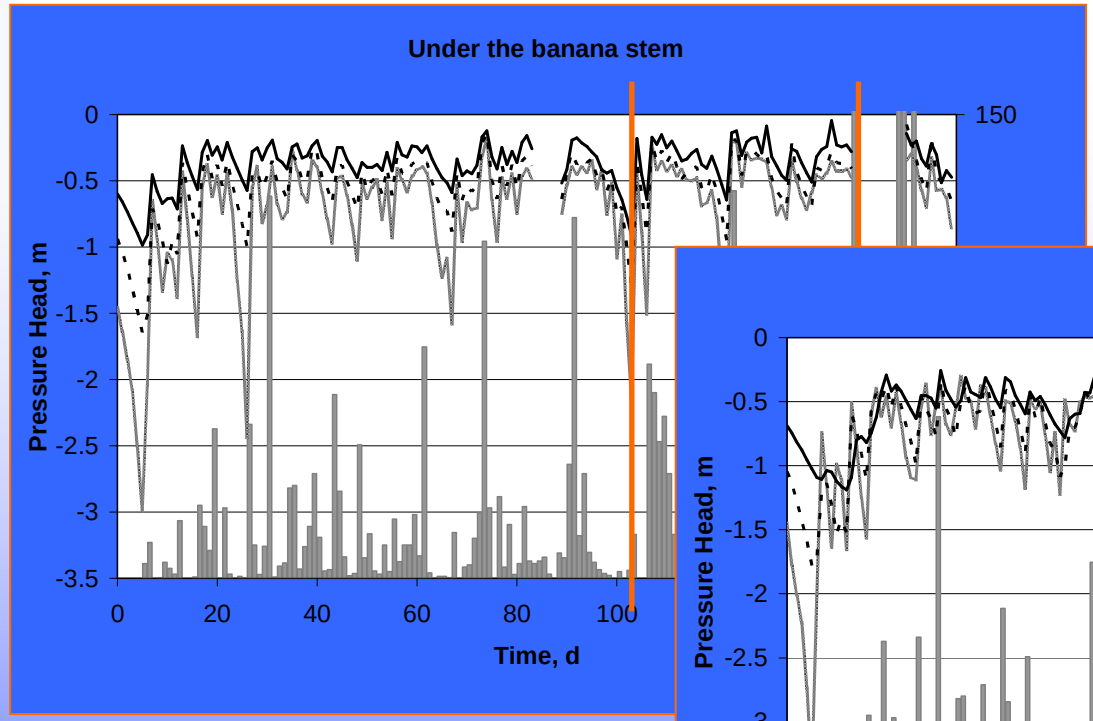
Physical properties of the Andisol

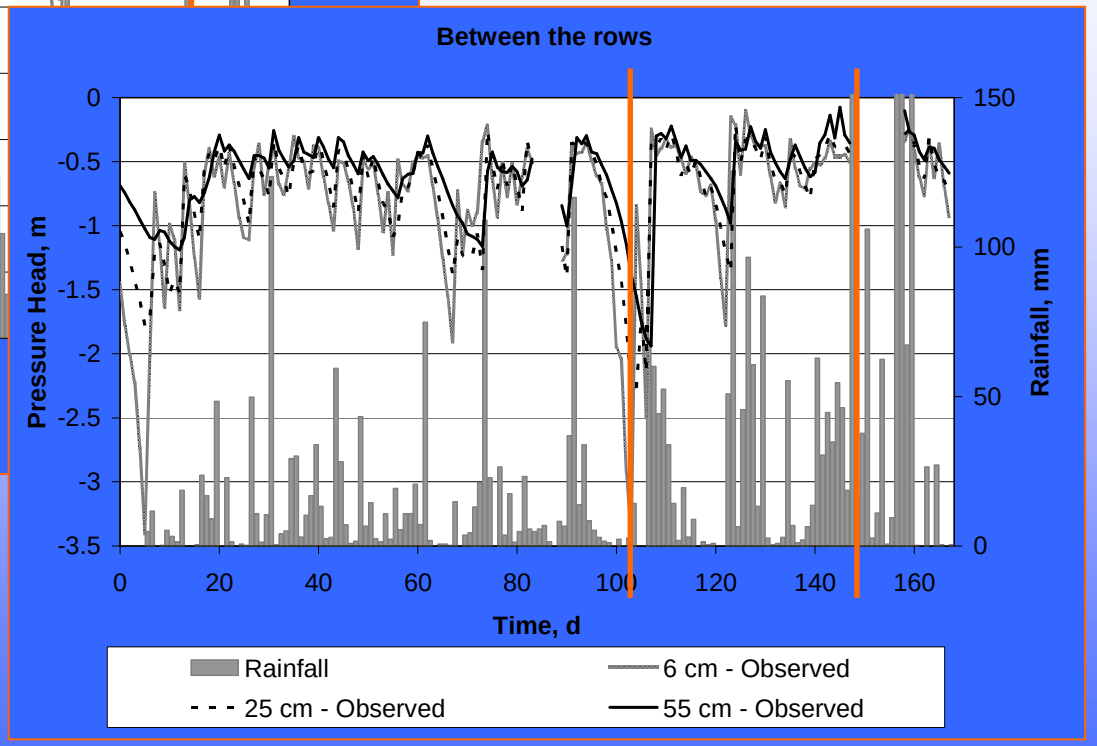
Horizon	Clay†	Bulk density	Organic C	Total porosity
	%	g cm^{-3}	%	m^3 m^{-3}
A	58.6	0.71	6.69	0.673
B	63.1	0.49	3.73	0.665

Effective soil hydraulic parameters

Material	θ_r	θ_s	α	n	K_s	l
	m^3 m^{-3}		m^{-1}		m d^{-1}	
A horizon	0.13	0.75	19.0	1.07	3	0.5
B horizon	0.11	0.75	23.3	1.05	1.06	0.5
Wick	0	0.63	0.06	3.61	280	0.5

Mean pressure heads measured with tensiometers





Simulating period

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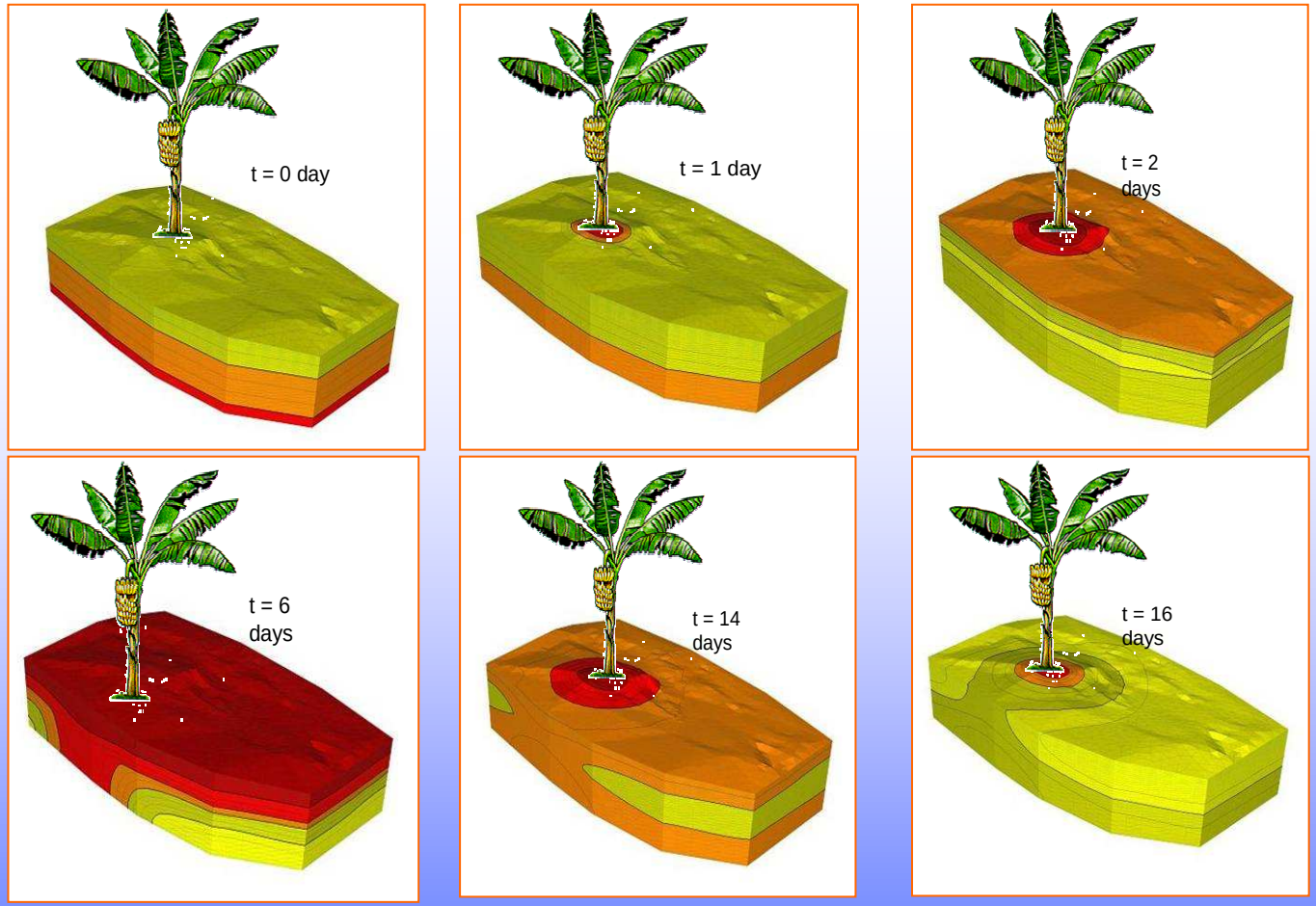
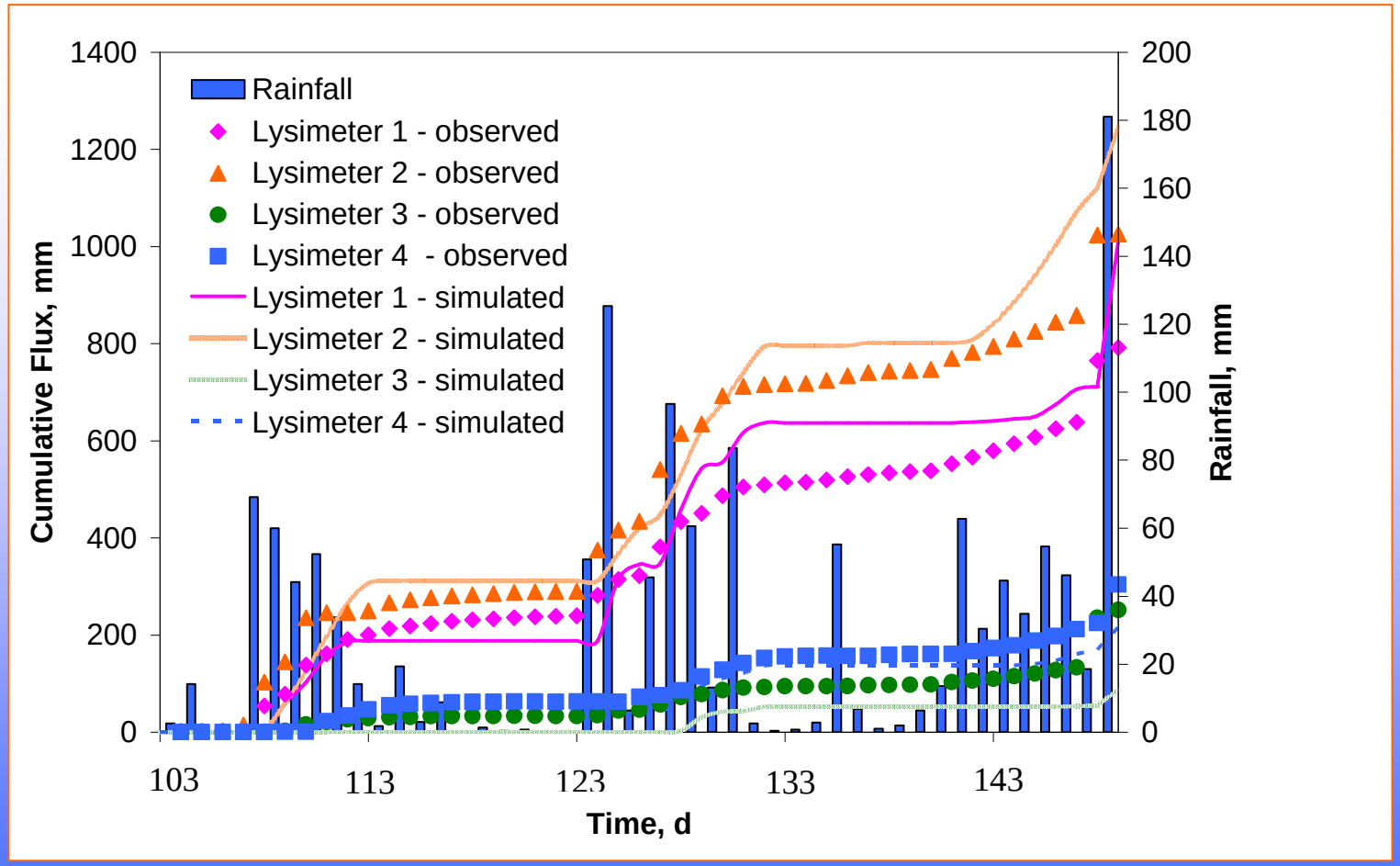


Measured and simulated cumulative fluxes from four lysimeters



Conclusion

❖ Using **experimental** and calculated drained volumes, as well as soil pressure head data, we attributed **drainage fluxes under the banana stem** or immediately downstream from the stem almost exclusively to **the stemflow**.

❖ **Simulations** showed that under heavy fluxes, such as those due to stemflow, **the wicks reproduced the actual field drainage reasonably well**. Under smaller surface fluxes (e.g., throughfall), measured water fluxes with lysimeters were, on average, 50% underestimated compared with simulated water fluxes without lysimeters.

❖ The spatially distributed water fluxes under the banana plant also considerably influence **solute transport**. Our results, *i.e.*, a concentrated water flow around the plant stem, bring into question the common practice of applying fertilizers and pesticides at the foot of the plant.

Wick lysimeters